U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
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SAFE PRACTICES
UNDER BLOWUP CONDITIONS

FOR THE

FIRE CREW BOSS

KEEP ALERT

LOOK UP ↑ LOOK DOWN ↓

LOOK AROUND ↻

LARGE FIRE OVERHEAD TRAINING

Contents

I. INTRODUCTION

The purpose of this large fire overhead training outline for the Crew Boss is to help him know more about blow-up conditions and safe practices to use. This training outline should be used for training both the cooperator and Forest Service Fire Crew Boss. We must assume leadership for training all of our Fire Crew Bosses.

Blow-up fires and safe practices to follow have always plagued the Crew Boss. The importance of the problem has again been pointed out by fire accidents during the past several years. There is need for practical, clear, concise instructions to the Crew Boss on this subject. As a start, the best available information has been listed and recorded in this outline.

For training purposes, a blow-up condition is defined as an explosive, violent fire behavior which is difficult to identify before it occurs.

This training outline is organized in the following main parts:

1. Instruction steps and key points to stress in Fire Behavior Fundamentals.

2. Instruction steps and key points for indicators of dangerous fire behavior (blowups).

3. Instruction steps and key points for the Crew Boss to follow for safe practices.

It is extremely important that the instructor use all experiences that can be brought to the attention of the Crew Boss to point out the key points and principles outlined in this training plan.

As a matter of interest the following is a quotation by Chief McArdle which points out his thinking on this subject of safety in fire fighting:

> "We all realize that fighting a forest fire is dangerous. It can't be made a soft job. Despite that fact, or because of it, we must assure every precaution to guard the safety of those who take on this tough assignment. Human life must never knowingly or carelessly be subordinated to other values."

For those who wish to go deeper into the scientific reasons underlying these brief instructions to the fire Crew Boss, a reference list is included at the end of this report.

It is recommended that a minimum of four hours be given each year to Fire Crew Bosses on the subject of blow-up conditions and safe practices.

To make most effective use of this training outline, a fire table or other means of demonstration should be used to point up the instruction and key points that are listed.

II. FIRE BEHAVIOR FUNDAMENTALS

(The material in this part was obtained from a number of sources, including the Region-4 outline for a one-day fire training school.) Time: 1 hour.

Example of Introduction: Successful fire fighting is based upon the knowledge of why a fire burns and what makes it spread. Fire is simply a rapid chemical combination of fuel, heat, and air. The basic principle of fire suppression is to remove one or more of these elements in the quickest and most effective manner. In order to do this, however, there must be some knowledge of the causes and reasons for fires acting as they do. The primary factors that influence the spread of forest or range fires are fuel, weather, and topography.

Fuels: Fuels are commonly divided into two main groups:

1. Flash fuels such as dry grass, dead leaves, tree needles, brush and small bushy trees.

2. Slow burning fuels such as logs, stumps, deep duff.

Weather: Weather factors with which you as a fire crew boss will be concerned are wind, moisture, and to a lesser degree, temperature.

Slope or Topography: Slope greatly affects the spread of fire in two major ways:

1. Preheating

2. Draft

Judgment is the major factor in determining the relative importance of all the elements which determine fire behavior. For example, continuity and arrangement of fuels are sometimes more important than volume. Given a certain volume of fuel, features of arrangement or position will influence spread as well as difficulty of control. If fuels are patchy, broken up by areas of thinner fuel, rocky or barren spots, the spread may be uneven and slow (blackboard illustration recommended). If these same fuels are partly on the ground and partly in the air--standing snags--spread may be by spotting, and with severe winds, this may cause a most difficult fire. It pays to look carefully at all conditions in sizing up a fire.

The fire crew boss must take advantage of known methods of sizing up a fire at a given time and predicting what will happen as the fire advances or as changes of weather occur. Now we will look into the fundamentals of fire behavior you should know as a Fire Crew Boss.

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FIRE BEHAVIOR

Time: 1 hour, 30 minutes

Class: Group Training

Chief Instructor and 1 or 2 Assistants

Note to Instructors: This training plan is designed to teach the fundamental principles of fire behavior to any group regardless of the knowledge level in other fields. However, once the student or trainee has a good knowledge of these basic principles, the level of use to which they are put may vary greatly, ranging from the use of a pulaski digging a fireline to the calculation of manpower and equipment needs on a major fire.

The course is designed to be used with a Fire Table, but can also be given without it, using charts or slides to illustrate instead of the table.

Location: Warehouse, shop, or similar building in which electricity is available and an open fire may be used.

Material and Equipment:

- Blackboard
- Chalk, white and colored
- Eraser
- *Fire Table
- Kitchen matches
- One pound coffee can w/small hole in cover
- Small blow-torch or gas burner
- Electric fan
- Blacksmith tongs
- Canvas, 4' x 4'
- Paper and easel
- Colored crayons
- Hygrotherograph chart w/record
- Psychrometric tables (Weather Bureau)
- Cigarettes
- Fuels: dry pine needles, dry sticks, branches up to 1" in diameter, small dry cones, green twigs, needles

(*See Appendix #3 - Chapter I, Fire Control)

A. Instruction Unit: What Makes a Fire Burn

Instruction Steps	Key Points
1. Fire Triangle	1. (a) Something to burn (b) Fuel exposed to air (c) Temperature raised to "kindling point" varies from 600 to 800° F. (d) Combustion is result

Light a match and explain that heat by friction ignites the phosphorus of the match.

Ignite dry pine needles and explain raising the temperature to the kindling point. Repeat, using heavier fuel (small dry twigs). Note that it takes longer with the same amount of heat. The length of time is an important factor to consider when calculating the chances of fires starting. Normally, the finer the fuel, the shorter the ignition time.

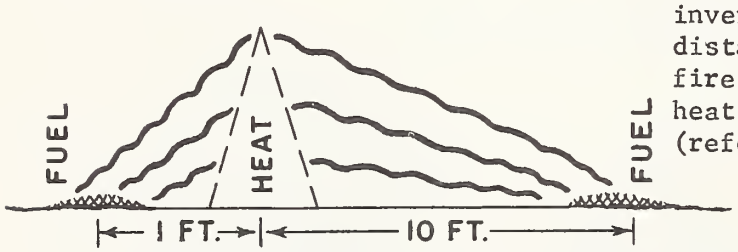
(e) Match common source of heat. Others are: lightning, cigarettes, sparks from flues, and heat from burning front after fire is started.

Lay one end of a dry stick in the fire and observe ignition. Allow the fire to burn along the stick held horizontally. Explain that only the particles immediately adjacent to or in contact with the source of heat are raised to the kindling point. Explain gases given off mixed with the oxygen of the air and carbon remaining.

Again refer to the triangle and the oxygen side. Normally, there is enough oxygen in the air to allow combustion to take place. Increase the supply of oxygen by forced draft and the fire will burn more rapidly. Remove the oxygen supply and the fire will go out.

A small fire in needles on the fire table. Lay a canvas over the fuel and remove after a few seconds. Note that the fire has gone out as the supply of oxygen is cut off. It may again burst into flames after the canvas is removed if enough heat is still present.

2. Radiation



2. Radiant heat decreases inversely w/square of distance; 10 feet from fire receives 1/100th the heat of fuel 1 foot away (refer to toaster).

Light a small fire in pine needles and observe the spread as adjacent needles are affected by radiated heat. Increase the volume of fuel on a portion of the area and note the increased intensity. Use a slice of bread to show increased radiation.

3. Firelines used to stop spread of fire.

3. Robs fire of fuel. Stops spread by radiation.

Demonstrate lateral spread with fire burning in all directions. Remove the fuel from the immediate path of the radiated heat. Note that a wider gap is required in the heavier fuels. Explain that the heavier the fuel or the larger a fire becomes, the more difficult it is to control. Note: Another factor (drafts created by the fire itself) is involved which has the effect of slowing down the spread. It is merely mentioned here and will be explained later.

4. Fuels separated do not burn as hot.

4. Stops effect of radiation.

Place three of four dry sticks in a bed of coals and observe how they ignite and burn as they are affected by the radiated heat from each other. Remove the burning limbs from the fire and separate them beyond the reach of the radiated heat of each other. Observe that the fire dies down or goes out. Again place them close together and they will soon burn up.

To illustrate a mop-up problem, show on the blackboard or chart a pile of logs burning on a hillside after the fire. Show them rolled out of their bed of coals and separated. Explain that the air temperature is cool, usually less than 100°, and the circulation of air has a cooling effect. Radiation is continuing and the fuel loses its heat.

5. Fire may be controlled by cooling down with water or earth.

5. Stops combustion by removing heat.

Demonstrate on the fire table and explain that the temperature of the earth beneath the surface of leaves is considerably below 100°, even in the summer.

6. Convection

6. Heat carried by the movement of hot masses of air which tend to rise by convection is heat transferred.

Show by the flames and smoke from a small fire on the fire table.

Hold a lighted match or small stick horizontally and note that the flame rising vertically has very little effect on the spread along the match, only the effect of radiated heat. Hold the match in a vertical position and note the effect. Heat by convection plus radiation increases the spread along the match stick.

Repeat the demonstration, using a dry stick or limb (approximately 1" diameter and 18" long). Ignite one end of the stick, held horizontally. Now (by means of blacksmith tongs) hold the stick in a vertical position in the center of a bed of coals on the stick. Next, keep the stick in its vertical position but move it outside of the bed of coals and observe that it ceases to burn.

Show a snag by means of the blackboard or chart. As the snag burns, the coals drop to the ground and accumulate, sending a column of heated air back up to increase the fire in the snag. Remove the coals (source of heat) from the base of the snag and the fire will die down. Similarly, roll a log out of its bed of coals and turn it over so that the heat is above the fuel.

Show effect of heat rising by lighting a surface fire in needles. Hold a branch over the fire to show how the fire will spread to low brush or low hanging branches of a tree and note that the heat from the fire in the needles ignites the brush. On the blackboard or chart, show the fire spreading to tree crowns and explain that it is the effect of the heat rising from the fire below that raises the temperature of the crowns. Explain that fire may be prevented from reaching the crowns by removing the brush before it is ignited.

7. First basic principle in fire control is to break leg of triangle (refer to fire triangle).	7. Remove the fuel "leg." Cut off supply of oxygen. Reduce the temberature.

B. Instruction Unit: Factors Which Influence the Spread of Fire

Introduction: Explain that success in fighting fire depends upon being able to anticipate the burning conditions of the future as well as to recognize those of the present. The fire fighter needs to keep himself informed of all factors which influence the spread of fire. In order to properly interpret information received from good scouting, fire weather forecasts and fire danger stations and apply it to control of the fire, a detailed knowledge of these factors is necessary. They are (1) fuels, (2) weather, and (3) topography.

Instruction Steps	Key Points
1. Forest Fuels	1. This is solid material needed for combustion.
(a) Flash fuels (grass, ferns, needles, moss, etc.)	(a) Dry out fast. Fire spreads rapidly. Provide kindling for larger fuel.

Illustrate by lighting pine needles or cheatgrass.

(b) Slow-burning fuels (logs, stumps). — (b) Dry out slowly. Fire spreads slowly, generates heat and hard to put out.

Illustrate by lighting heavier fuels.

(c) Quantity of fuels. — (c) The greater quantity - greater volume of heat, damage greater, cost to suppress higher.

Demonstrate by lighting first a very thin layer of fuel on the fire table and next a thick layer of fuel.

(d) Arrangement of fuels. — (d) Loose fuels burn more rapidly. More oxygen and dry out faster than compact fuels.

Light the open corner of a magazine and note that it burns slowly as the temperature is raised. Open the magazine--thus exposing the pages of the magazine to more oxygen causing them to burn more rapidly.

Cover the fire table with oak leaves. Ignite the leaves and note the rate of spread. Stir the leaves and note increased rate of spread.

2. Fire Weather

(a) Fuel moisture. — (a) Amount of fuel moisture together with wind, largely determines whether fires will start and spread. Result of weather effects upon fuels. Fuels over 25% nonflammable, fuels under 25% flammable.

Select two sticks approximately 1" in diameter, wet the surface of one and leave the other dry. Hold the sticks over a small fire or flame from a burner. Observe the moisture evaporating from the wet stick as steam; also ignition taking place in the dry stick first. Compare the length of time each stick must be exposed to the heat before ignition takes place.

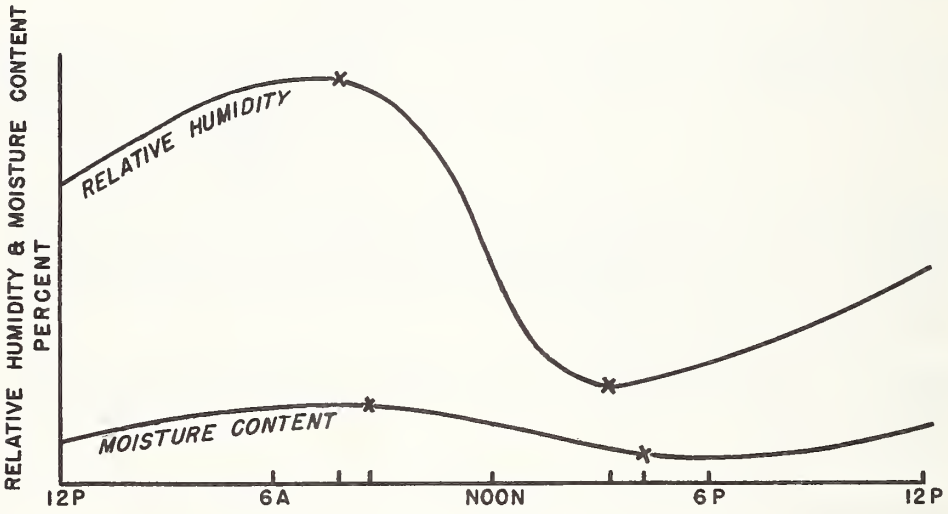
Cover the fire table with a light covering of fuel and ignite across one end. Spray the fuel on half the width of the table. Compare the rate of spread when the fire reaches the wet fuel. If the fuel is wet only enough to slow up the rate of spread,

you will note that the wet fuel will continue to burn slowly as the heat dries out the fuel. If the above demonstration is repeated, using varying amounts of moisture, it will be noted that the more moisture applied the slower the rate of spread until finally the fuel will cease to burn.

(b) Daily trend of fuel moisture.

(b) Effect of humidity. May not occur in fall when east winds might blow all night.

Show on the blackboard or chart how moisture content of fine fuels changes with humidity during 24 hours.



(c) Soil Moisture

(c) Important in its effect on fuel moisture. Different spring and fall.

(d) Relatively Humidity

(d) Important in not only its direct effect on fuel moisture, but also causes fires to start easily and spot readily when very low. Easily measured. Guide to burning out.

(e) Temperature

(e) Chief effect on combustion is that an increase in air temperature causes a decrease in humidity.

(f) Wind

(f) Direction - can be dry or moisture laden. Velocity - supplies oxygen to fire, bends fire closer to unburned fuels and carries sparks and burning fuel ahead of fire to start spot fires.

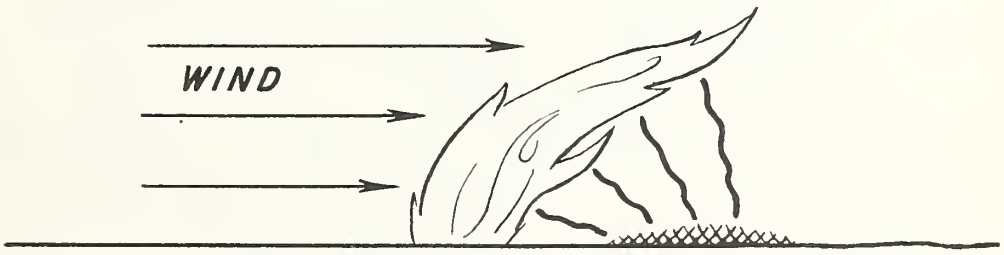
Prevailing and local. Daily trend of local - up canyon in day, down at night.

Demonstrate the influence of wind on rate of spread:

(1) By augmenting the normal supply of oxygen, <u>direct the wind</u> from an electric fan into a small fire in pine needles on the fire table. Observe the increased rate of combustion which results from the increased supply of oxygen.

(2) By changing the position of the flame, <u>direct the wind from the fan in the direction the fire is spreading</u> under existing conditions and observe the increased rate of spread. Note the angle of the flame in relation to the fuel. The radiated heat has a shorter distance to travel and is therefore more intense upon the fuel's surface.

Show on the blackboard or chart the angle of the flame in relation to the fuel.



(3) By changing direction of the convection current, repeat the demonstration under number 2, <u>using heavier fuel and stronger wind</u> and note the convection heat as indicated by the smoke being directed through or close to the fuels ahead. This has the effect of preheating the fuels ahead of the radiated heat. Also, the cool air coming in from the rear has a cooling effect on fuels.

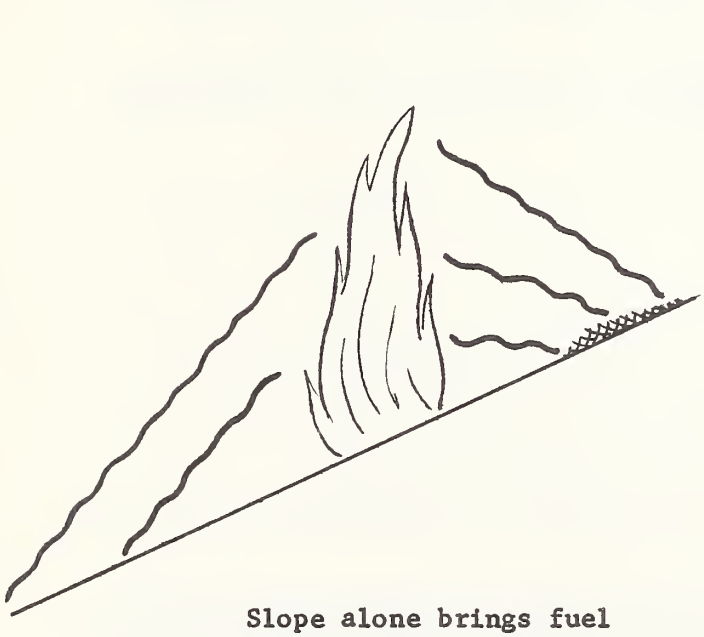
In field application this results in what is called the head or front and the rear of a fire. The spread at the rear of a fire is usually very slow and easy to work while the rate of spread at the head is fast. It is oftentimes dangerous and sometimes impossible to work the head or the flank toward which the wind is blowing.

(4) By carrying fire into the fuel ahead; direct a strong current of air from the fan into a fire burning in leaves or hot embers. Observe the spotting ahead which results in ignition in advance of the main fire.

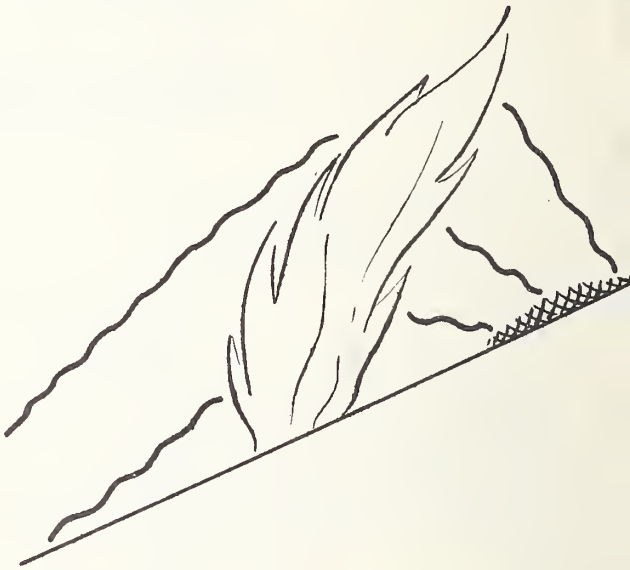
3. Topography

(a) Aspect — (a) Direction of slope, N, NE, E, etc. Effects fuel moisture (S vs. N aspect).

(b) Slope and Drafts — (b) Effects heat transference by bringing flame closer to fuels and by increasing drafts. Speeds up spread of fire in uphill direction. On very steep slopes spread is increased downhill by roll.



Slope alone brings fuel closer to flame.



Slope bends flame closer to fuel by convection.

On raised end of table covered with needles, start a fire at the top edge. Observe how slowly it burns downhill.

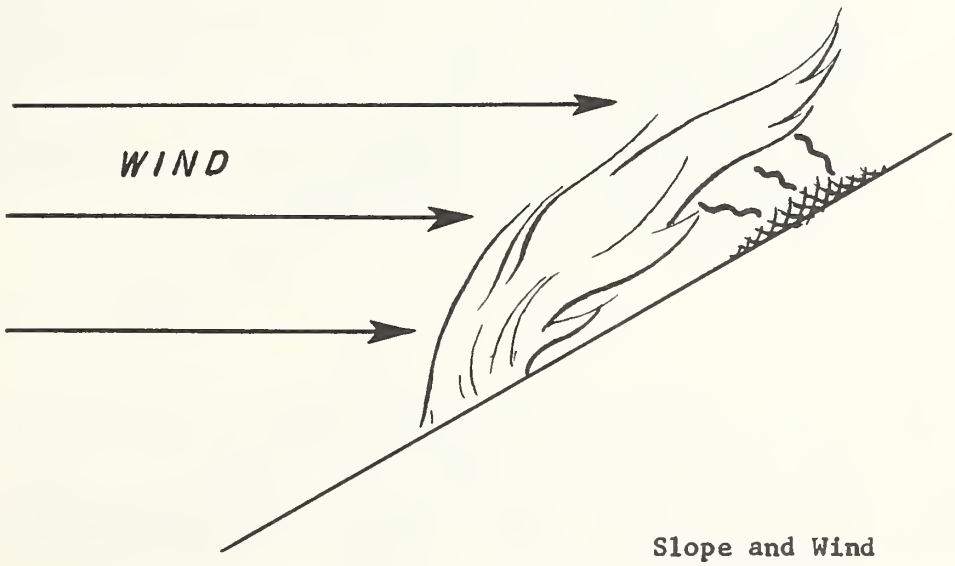
Flames and radiated heat directed above and away from fuel. Repeat and light the fire at the bottom edge of the slope. Observe the rapid spread up the slope. Note that the fuel is closer to the flame. Also, the draft created by the fire tends to follow the slope carrying the heat and flames toward the fuel which has the effect of preheating the fuel well in advance of the fire itself. Observe that the fire burns up the slope wedge shape, as a result of the concentration of the draft near the center of the fire. Note, also, that the drafts are into the fire on both flanks. In application, this permits working the flanks even of a fast running fire.

Show on the blackboard or chart how the shape of the front will vary according to the steepness of the slope and the volume of fuel.

Downhill "Roll"

Demonstrate by covering the raised end of the fire table with a covering of needles and place a few small cones on the slope. Light the fuel at the top of the slope and observe that the cones roll down as the fuel is burned away, causing an increased rate of spread downhill. Note that the steepness of the slope has a decided effect on the danger of rolling; also, some fuels are more apt to roll than others. Burning logs and hot coals are examples of rolling material.

Show on the blackboard or chart the technique of preventing burning material from rolling downhill, i.e., trenching.



Slope and Wind

(c) Exposure

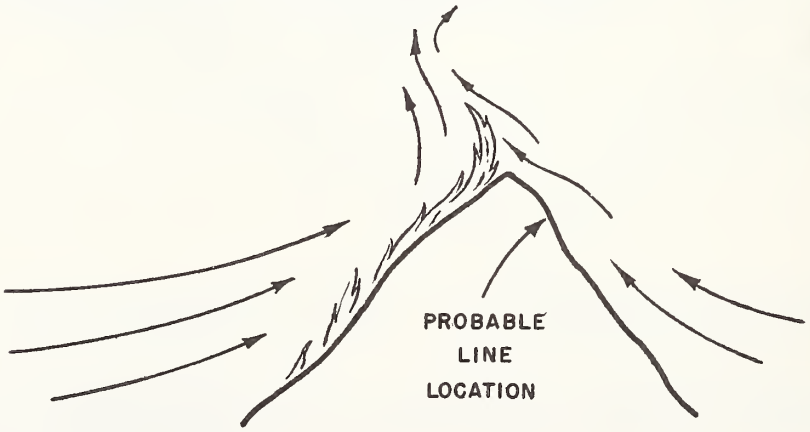
(c) Fire is more exposed to winds in areas of broken topography. Control is made more difficult by drafts created and local winds.

Demonstrate the effect of a combination of slope and wind when the wind is across or is at an angle to the slope. Light a fire across the lower end of the raised portion of the table. Direct the fan across the table. Observe that the fire travels up the slope at an angle. Note that the wind counteracts the effect of slope or vice versa. In application, there is usually some up-canyon wind which causes the fire to burn up-slope at an angle. The angle will vary according to the characteristics of the convection column on the slope and the velocity of the wind. Also, a gentle to moderate slope will have little effect on a fire traveling with a strong wind.

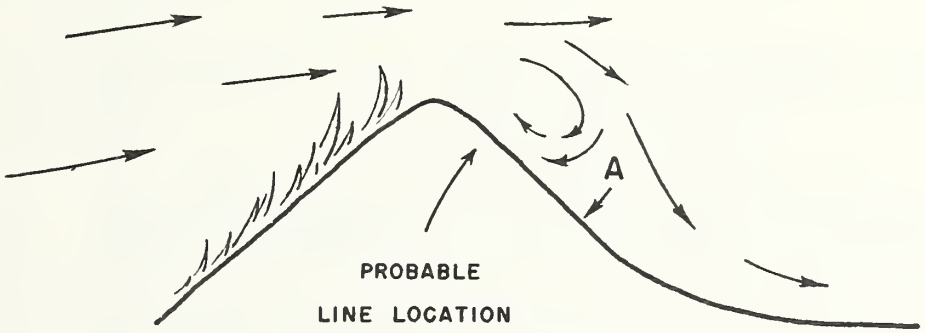
A fire burning the width of the table in needles. Observe that there is a draft toward the head and flanks of the fire. From a narrow line start a backfire and observe the increased spread as the backfire approaches the main fire. In application, the heat and draft created by the main fire can be observed by movement of leaves or twigs of trees and by smoke columns. On a large fire the draft is usually stronger on one side of the fire, higher on account of a supplementing breeze mentioned above, or freer access as a result of the fire burning on a slope, which is the next factor discussed.

Light Wind Condition

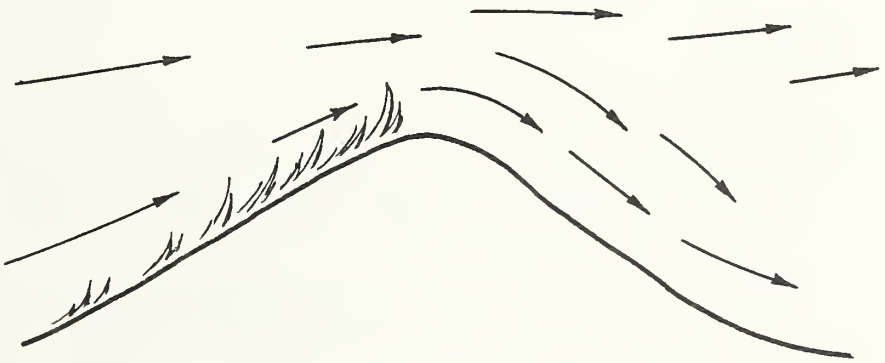
Show on blackboard or chart that as a fire approaches the top of a ridge when wind conditions are light, it is affected by the natural updraft on the opposite slope. This, together with the inrush of cool air displacing the mass of warm air rising at the head of the fire, results in a definite slowing up in the rate of spread. Also, the updraft from the opposite slope counteracts to a certain degree the draft created by the fire and results in the smoke and burning embers being carried back over the fire area. In practical application this permits firing out and holding line a short distance over the ridge from the fire.



With moderate to strong winds blowing across a ridge, a horizontal or "roll" eddy frequently forms on the lee side of the ridge. When this occurs the wind direction on the lee side may be opposite in direction to the general wind. As with the light wind condition, this favors construction of a line a short distance over the ridge where there will be a favorable wind for firing and holding. Care must be taken not to build line at the lower edge of the eddy (Point A) since the fire may be driven in both directions. Spot fires are particularly dangerous in this area.



In coastal areas where marine air flows inland, the relatively cool and heavy air will follow the topography closely and will carry the fire downslope nearly as fast as upslope. This condition is most likely to occur at night or late afternoon.



The steepness of the slope opposite the fire, the type of cover on the slope, whether it is a north or south exposure, presence or absence of marine air, and the depth of the canyon all have a bearing on wind or draft conditions along ridgetops.

4. Fire Factors	4. Habits
(a) Daily trend in humidity and fuel moisture.	(a) Generally, worst burning will be between 10:00 a. m. and 5:00 p. m.
(b) Daily winds	(b) May blow quite hard at definite periods of day
(c) Volume of heat	(c) Buildup during day causes greater spread of fire.
(d) Recognition of these factors affecting fire behavior important to successful suppression.	(d) Need to anticipate what may happen. Daily trends may not occur.

III. INDICATORS OF POSSIBLE UNUSUAL FIRE BEHAVIOR (Blowups) Time: 2 to 3 hrs.

Occasionally a forest fire burns with an intensity that seems far out of proportion to apparent burning conditions. Each blowup fire raises the question: What can we do to recognize conditions causing extreme fire behavior? How can we predict these conditions in advance? The following on-the-ground indicators should be watched for as they may mark extreme burning conditions that will follow:

Instruction Steps

1. Fast burning fuels

Indicators

(a) Unusually dry fuels.

(b) La rge amounts of fine fuel (grass, needles, moss, etc.) particularly where continuous and on steep slopes.

(c) Crown foliage dried by surface fire over large area.

(d) Brush and conifer tree foliage after prolonged drought.

(e) Concentration of snags.

2. Weather factors

Indicators

(a) Strong winds blowing.

(b) Unexpected calm. May result in winds shifting.

(c) High clouds moving fast may result in unusual winds on ground.

(d) Unusually high temperatures early in morning.

(e) Look for dust devils and whirlwinds.

(f) Thunderheads above or in close proximity to fire usually leads to dangerous down-draft winds. If thunderhead is upwind of the prevailing wind, the danger is greatest.

(g) When slope becomes shaded, look out for downdrafts.

(h) If a fire is burning near a mountain or glacier (such as Mt. Hood), greater downslope wind velocities will normally occur.

(i) Keep an eye on smoke column. Winds may be blowing from different directions above fire. This could result in spot fires outside.

(j) Watch smoke column for an increase in wind speeds aloft. This leads to spotting, and gusty wind conditions may also result.

(k) Sudden changes in direction and/or velocity of wind when weather fronts move in.

3. Fire behavior (which could lead to a blowup)

Indicators

(a) Spotting ahead of fire or downslope below line being worked.

(b) Intense burning inside fireline.

(c) Smouldering fires over a large area.

(d) Many simultaneous fires starting.

(e) Whirlwinds inside fire causing spots and creating intense, erratic burning.

(f) Broadcast crown fires in brush or timber.

IV. SAFE PRACTICES FOR CREW BOSS TO KNOW AND USE — Time: 2 to 3 hrs.

Introduction: The Crew Boss has two main responsibilities:

1. To obtain an effective, fair day's work from his crew and

2. To look after the safety and welfare of his crew 24 hours a day to the best of his ability.

You know how to recognize conditions leading to "blowup" fires. Now we are going to share our experiences in knowing what safe practices to:

Know and use to prevent injuries or loss of life during blowup conditions.

(Note to Training Leader)

As you put across the following instruction steps and key points listed below, please:

1. Review with group and stress key points.

2. Encourage Crew Bosses to relate actual experiences they have had on a fire to stress key points.
3. Relate experiences you have had to illustrate points.
4. Use case histories of disasters or near misses.

Instruction Steps

1. STAY ALERT. Be prepared for safe emergency action. KEEP YOUR HEAD.

   Key points

   (a) Heads up: Look Up, Look Down, Look Around.

   (b) See what you look at.

   (c) Know where the fire is and how it is behaving at all times. If necessary, use scouts or post lookout with proper communication.

   (d) Know what danger signs to look for, including fatigue. Use your Fire Behavior Know How.

   (e) THINK before Acting. Pause, Think, then Act.

   (f) Fire fighting is dangerous. Crew Boss has a KEY job. Men are looking to the Crew Boss.

   (g) Keep an up-to-the minute plan of get-away action in mind.

   (h) ACT with decision and promptly when escape action is needed.

   (i) Remember--a fireline is not usually safe until it is burned out.

   (j) The spectacular fire may not be the most dangerous. The quiet-looking fire may be the most hazardous.

   (k) Get weather forecast in morning.

2. Work and act as a team.

   Key points

   (a) Gain confidence of crewmen.

   (b) Keep crew together. Need to do this for clear, safe actions.

   (c) Use action words: "Come Here," "Follow Me," "Keep Together." The Crew Boss is the leader.

(d) Don't assume anything. Crew Bosses have said, "Let's go" and men have gone different directions.

(e) Know where all your men are.

(f) Men must follow all verbal orders and stick together when orders are given to move out.

(g) Have men keep hand tools as they may be of value in providing protection.

(h) Assign most experienced, mature men for scouting and for lookout when in especially hazardous situations. Arrange for prompt communication.

(i) Manage and control your men.

3. PLANNED GET-AWAY, including ESCAPE ROUTES.

Key Points

(a) Crew Boss must always have in mind a clear-cut plan of action for fire "blowups." Know in advance where you will lead your crew. If necessary, prepare and mark escape route in advance.

(b) Let your crew members know you are responsible for their safety.

(c) In the event of a blowup, pause a moment and size up the situation. Then think clearly, speak decisively, and act in a calm and deliberate manner.

(d) Remember danger potential of timber, brush, and grass fire fighting.

(e) Keep Crew informed.

(f) Keep in mind open places such as rock slides, streams, burned over places, meadows, alder patches, and gravel bars.

(g) One of the safest spots is burned over area. If needed, dig in.

(h) When not possible to get into burned area, remember, men can travel faster downhill or along contour.

Warning--Remember, winds usually blow downslope at night and fires can run rapidly downhill.

(i) If necessary to jump through burning edge of fire, have men place hat or coat over face.

(j) Caution men: if clothes catch on fire, roll on ground in dirt to put out fire.

(k) DO NOT travel ahead of fires in direction of spread unless you are positive that a safe place ahead can be reached by crew.

(l) When not possible to get within burn, pick most open ground possible and avoid dense brush. Men become separated and go astray.

(m) After reaching escape spot, check to be sure it is safe from falling trees, snags, rolling logs, or rocks. Try to find a safe vantage point and post lookout.

(n) In any brush fire fighting, when working in advance of fire with dozer, build safety strip for retreat.

(o) In timber types, sharp ridgetops are good bet to get to if possible.

(p) Watch for safer topography, benches in steep country.

(q) As last resort, burn out and dig in.

(r) When at safe spot, remember suffocation has killed. Have men keep damp cloths over their noses and get next to ground.

(s) Where heliports exist, keep their location in mind.

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